

Organizational factors for manufacturing defects reduction in small batch production

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Abstract. The study is devoted to the defects organizational causes analysis in the machine building products production process. The companies with the small batch production were taken into consideration. Factors related to the time norms fulfilling percentage, the work rhythm, the consolidation of operations at one workplace, the new technologies introduction and equipment failures were chosen. A preliminary factors selection according to independence criteria allowed us to build a reliable regression model for the defects rate calculating. The main factors influencing the defects rate in small batch production are the time norms fulfilling percentage, the rate of consolidation of operations at one workplace, and the number of new technological processes introduced. This allowed us to offer recommendations on the machining sites work organization. The final operations and products which are made from expensive metals should be carried out at workplaces with a low rate of operations consolidation. Also, it is important that the wage system should not contribute to over-fulfillment of norms. The maintenance and repair system should prevent malfunctions during operations fulfilment.

1. Introduction

Product quality management concepts change according to the production development. The traditional quality assessment methods are based on large statistical samples of indicators. Application of Shuhart control cards is described, for example, in [1]. In [2] the shortcomings of Shuhart maps are identified and improvements for this method are offered. The statistical concept of ‘six sigma’ is widely used to improve the processes quality and to identify the reject causes [3].

This does not applicable to small-batch manufacturing and customer-oriented production. This conclusion is made in the article of [4] and confirmed by Russian investigators [5]. In the context of uncertainty in small-batch manufacturing, it is difficult to determine the reject causes from the product sample. The authors [6] propose to use a combination of statistical and Bayesian approaches. This requires the use of the aprioristic judgment on the reject reasons.

The reject reasons can be technical, organizational and connected with human resources. Technical reasons related to equipment and tool deterioration are quite widely considered (for example, in [7]) and are not the subject of the research. The human factor is also studied in detail. Most often, the influence of the human factor is connected with the workers’ motivation [8]. Other authors consider the relationship between the quantity of defective products, caused by the workers’ errors, and the complexity of design and technology [9]. This is relevant for labour-consuming processes such as assembly. These factors are also important for metalworking but to a lesser extent.



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The organizational factors are in the greatest interest of researchers. In [10,4] the products quality is considered as a consequence of the industrial system construction quality, including production logistics, maintenance, management and control methods. This is a comprehensive approach for the entire production system. The quality issues of raw materials and components, which are also related to the control factors, go beyond the scope of the production process and are not considered in the work. They are discussed in other investigations, for example [11].

The purpose of the investigation is to determine the organizational factors of the reject during the metalworking operations at a particular workplace in small-batch manufacturing.

2. Materials and methods

The investigation is based on actual operation data of the mechanical processing workshop during the year. The main method of research was regression statistics. The choice of the reject factors was based on an analysis of researchers' work on the subject and the expert assessments of the reject.

The main factors selected for the analysis are:

- Index of labour performance (X_1);
- Amount of the overtime work in the workplace per month (in hours) (X_2);
- Amount of new technology in the workplace, previously not performed here (X_3);
- Index of the fixed operations (the amount of different operations completed at the workplace) (X_4);
- Number of equipment malfunctions (X_5).

The investigated function (Y) is the share of reject in the total volume of production.

The data for analysis are shown in Table 1.

Table 1. Data for analysis.

Month	Y	X_1	X_2	X_3	X_4	X_5
1	3.9	1.071	8	1	23	0
2	3.7	1.039	0	0	24	0
3	3.8	1.055	0	0	24	0
4	4.3	1.108	2	0	26	0
5	6.5	1.203	8	1	34	1
6	7.1	1.222	10	2	37	1
7	8.2	1.251	16	1	43	2
8	6.7	1.211	12	0	39	0
9	7.2	1.232	16	2	41	1
10	8.5	1.267	16	2	45	2
11	4.4	1.112	0	0	26	0
12	9.1	1.327	20	5	49	2

The importance of the 'overtime accounting' factor is noted in [12] as a part of the optimal production program model creation. The need to take into consideration the change in technology is described, for example, in [13, 14]. The remaining factors are selected on the basis on the expert estimates of managers.

The data was processed using the Microsoft Excel.

3. Results and discussion

On the first stage of the investigation, a multi-factor regression model was used. The influence of all 5 factors was taken into consideration in the model. This model shows a high determination coefficient ($R^2 = 0.99$). But the statistical significance coefficients evaluation of the multi-factor model showed that two factors from the considered set (X_2 and X_3) have an unacceptably high level of P-values (significantly higher than the normative level of 0.05) and therefore are not statistically significant. The second stage of the investigation, these factors (X_2 , X_3) were excluded from the multi-factor model.

As a result, the model became:

$$Y = -7.1999 + 8.2358 \cdot X_1 + 0.0972 \cdot X_4 + 0.4146 \cdot X_5 \quad (1)$$

Model coefficients are statistically significant. The determination factor has a high value. Fisher's test value is improving.

The model reflects the share reject dependence from: the index of labour performance, the Index of the fixed operations and number of equipment malfunctions. At the same time, if independent parameters are close to 1 (or 0 in the case of equipment failures), then the reject share according to this model will be extremely small. Therefore, this formula is not effective when used in mass and large-scale production. Because in these types of production fixed operations index does not change from month to month, and the labour performance index is more stable, as most actions of the worker are automated. The formula could not also be applied in single production because in single production usually each operation performs for the first time and once. It can be called a 'permanent implementation'. In addition, time standards in single production are calculated by extended methods and often do not correspond to reality. The model can be used only in small-scale and medium-scale production.

Using this model, the following recommendations for workplace production can be formulated:

1. Final operations have to be carried out at workplaces with a small index of the fixed operations.
2. The products from expensive materials have to be produced on the workplaces with a small index of the fixed operations.
3. The remuneration system should not encourage over-performance.
4. The repair, maintenance and operation of the equipment have to prevent problems during operations.

Thus, it is more efficient to have one pre-operation equipment working in 2–3 shifts and several workplaces for final operations working in one shift.

Similar situation is with material. It is more efficient to have one equipment, rolling black metals, working in 2–3 shifts, and several workplaces, rolling non-ferrous metals and alloys, working in one shift.

At the same time, both the cost of the material and the processing stage must be taken into account. During the production reorganizing, it is necessary to factor into the reduction of costs and the constant quality improvement, which are necessary in the strict competition conditions. Therefore, special creation of several workplaces for final operations may be economically unprofitable. This requires additional calculations.

The remuneration system has to reduce the share of reject and the corresponding costs associated with the defective products production. According to the mathematical model, the proportion of reject depends on the rate of standard time implementation. Accordingly, the remuneration system has not to encourage the overtime work. The Russian enterprises in metal-working industries very often use the piece rate system. It is necessary to provide transition to time system with normalized task.

The share of reject is affected by equipment problems. planning and preventive systems of equipment repair and maintenance can be used for equipment problems preventing [11]. In order to update the equipment maintenance and repair system, it is necessary to develop the scheduled repair system for modern CNC machines, as well as to create internal standards for maintenance and operation of the workplaces. The standards can be based on the 5S system [12].

Since the first three recommendations are limited in application, more attention should be paid to the fourth recommendation – preventing equipment problems by improving the equipment repair and maintenance system.

4. Conclusion

A machine-building enterprise wishing to reduce the reject should pay attention to the system of maintenance, repair and operation of technological equipment; to the basis of the defect-free labor stimulation system and the organizational principles of products movement along the technological

route. That would help the enterprise successfully compete and introduce innovative technologies and equipment.

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